

## **Payload Integration Agreement (PIA) for the Alpha Magnetic Spectrometer-02 (AMS-02) Payload**

This PIA revision supersedes and replaces the previous AMS-02 PIA, OZ-12-002, dated March 2012.

This PIA documents the joint management agreement between the International Space Station (ISS) Program and the Johnson Space Center (JSC) Engineering Directorate to manage and execute the integration requirements for ground handling, transportation services, and for on-orbit operations of the AMS-02 payload. The ISS Program and Space Shuttle Program (SSP) will provide best effort to carry out all agreements with the AMS-02 payload as documented in this PIA.

The AMS-02 experiment is a state-of-the-art high energy physics experiment using numerous detectors and a permanent magnet designed to search for anti-matter, dark matter, and other astrophysical phenomenon. This unique scientific mission of exploration seeks to understand fundamental issues shared by physics, astrophysics, and cosmology of the origin and structure of the Universe. The AMS-02 is designed, constructed, tested, and operated by an international collaboration organized under the United States Department of Energy (DOE), in its role of payload sponsor and under an inter-agency implementing arrangement between the DOE and National Aeronautics and Space Administration (NASA).

For transport to ISS the AMS-02 payload requires an SSP Orbiter launch. The AMS-02 payload consists of an external system and a pressurized system. The external system is a Unique Support Structure-02 (USS-02) structure employed to support the AMS-02 permanent magnet, its science detectors, and provides the direct interfaces for the AMS-02 in the Orbiter's cargo bay, the robotic grapple fixtures used during transfer and deploying of AMS-02 to International Space Station (ISS) and the external Payload Attach System (PAS) site. The USS-02 is comprised of the following subassemblies: Upper USS-02 Assembly, Permanent Magnet Assembly, Lower USS-02 Assembly, Keel Assembly, and the PAS/Umbilical Mating Assembly. The USS-02 primary structural members consist of extruded tubing with aluminum walls fastened with rivets and bolts. The permanent magnet system is fastened within the USS-02 utilizing the vacuum case, a double X structure and strut system.

The science determination of whether a particle is anti-matter, or evidence of dark matter, is made possible through the use of a permanent magnetic field that will bend the path of charged particles, thereby indicating whether the particle is anti-matter or matter. AMS-02 is a complex payload with six science detectors designed for specific types of particle analysis in addition to the payload's support systems that allow the detectors to perform science collection. The six science detectors are: (1) Transition Radiation Detector; (2) Silicon Tracker; (3) Time-of-Flight Scintillator Counters; (4) Ring-Imaging Cerenkov Detector; (5) Electromagnetic Calorimeter; and, (6) Anti-Coincidence Counter.

The AMS-02 experiment pressurized system is an ISS Digital Data Recording System (DDRS) Expedite the Processing of Experiments to Space Station (EXPRESS) sub-rack payload. The station AMS-02 ISS DDRS operations strategies are based on a T61p Laptop, dedicated for AMS-02 use which allows increased payload operational flexibility and better protection of AMS-02 data during early on-orbit power-up operations and payload science systems steady state operations. The ISS crew interface with the AMS-02 ISS DDRS for crew monitoring of payload health status, contingency keystroke commanding, and hard-disk change-out. The primary controls of AMS-02 (command and telemetry) are from the ground.

The joint agreements between the AMS-02 Project Office and the ISS Program are documented in SPIA SSP 57061 and SPIA SSP 57072 (responsibilities, tasks, requirements), this PIA (unique payload agreements), the Payload Data Sets (detailed technical requirements), and the payload unique ICD (interfaces/verification requirements). The AMS-02 Hardware ICD documents the hardware definition to ensure compatibility with the ISS and the appropriate launch vehicle/carrier and verification activities to satisfy requirements. The Space Station Payloads manifest, resource allocations, and payload unique requirements are provided in the Increment Definition and Requirements Document Annex 3: Imagery Requirements and Annex 5: Payload Tactical Plan.

Deviations from SSP 57061-Revision B and SSP 57072 are documented in the following tables. Unique agreements that have been coordinated between the ISS Program and the AMS-02 Project are noted in the table below.

Deviations from SSP 57061-Rev B and Unique Agreements

| SPIA 57061<br>Section/<br>Paragraph<br>Number | PIA Agreements  |
|---|---|
| 1.0   | <p>Payload hardware provisioning supports the AMS-02 launch on STS-134/ULF6 in the Orbiter's cargo bay. The primary science mission is the collection of particle data over 10-years of continuous nominal science operations in conjunction with the permanent magnet. The majority of the remaining avionics power must be maintained to thermally control the payload given potential station attitudes. The payload must be powered and operational or powered to thermally maintain the payload science detectors within survivability levels.</p> <p>AMS-02 will be located at the zenith/inboard S3 Integrated Truss Assembly (ITA) Payload Attach System (PAS #2) site, with the center axis of the payload canted 12-degrees inboard to provide maximum clearance for the envelope of the adjoining payload and to reduce impingement of the AMS-02 field-of-view by the ISS photovoltaic arrays. The AMS-02 will be certified for up to 11 years of operations.</p> <p>The following SPIA SSP 57061-Revision B paragraphs are applicable to ESA, JAXA, CSA, and Spacehab, and do not apply to AMS-02: 3.1.2 and sub-paragraphs; 3.1.3 and sub-paragraphs; 3.1.4 and sub-paragraphs; 4.2 and sub-paragraphs; 4.3 and sub-paragraphs; 5.3 and sub-paragraphs; 5.4 and sub-paragraphs; and, paragraphs 5.5.3; 5.5.4; 5.5.6; 5.5.7; 5.5.8; 5.5.9; 5.5.10; 5.6.2; 5.6.3; 6.2; 6.3; 6.4; 7.1.1.4; 7.1.2.3; 7.2; and, 7.3.</p> |
| 3.1.1   | <p>The AMS-02 Project shall provide the analytical integration data products and models of the AMS-02 experiment flight hardware to the ISS Program, via the ISS Payloads Office, and to the Space Shuttle Program for the launch configuration.</p> <p>The ISS Program shall provide the ground processing of the AMS-02 on a Space Shuttle flight, perform all the physical integration and ground processing engineering for integration of payload hardware to Shuttle, and provide all necessary ground processing integration services.</p> <p>The AMS-02 Project will generate the AMS-02 a Flight Safety Data Package and a Ground Safety Data Package for submittal to the Payload Safety Review Panel (PSRP) and Ground Safety Review Panel (GSRP).</p>   |
| 5.0   | <p>The AMS-02 Project will provide the AMS-02 flight-certified hardware listed in the Payload Furnished Equipment list as available for flight. NASA/ISS is responsible for verifications showing that Government Furnished Equipment (GFE) provided hardware is certified for flight.</p>  |

|  |   |
|--|---|
|  | <p>End of mission statement: There is no return requirement for the AMS-02 ISS DDRS internal system. The AMS-02 ISS DDRS system may be left on orbit and/or dispositioned at the ISS Program's discretion with AMS Project concurrence.</p> <p>The following SPIA SSP 57072 paragraphs do not apply to AMS-02 ISS DDRS: 5.1.1; 5.1.2; 5.1.4 5.1.5; 5.1.6; 5.1.7; 7.1.2; and, 7.2.2.</p> |
|--|---|

The AMS-02 Project listing of ground and flight Government Furnished Equipment (GFE) requests to the Space Shuttle Program and ISS Program are documented in the following tables. Availability and approval of the Space Shuttle Program and the ISS Program certified flight hardware usage is considered complete with approval of this PIA and approval of the statements within the STS-134/ULF-6 Mission Integration Plan (MIP) with the Space Shuttle Program.

SSP Government Furnished Equipment (GFE)

| Delivered | Equipment  | Quantity | Part Number     | Use    | Duration of Use | Hardware Provider |
|-----------|--|----------|-----------------|--------|-----------------|-------------------|
| Yes       | See Note 1 and Note 2                                    | Note 1   | Installed       | Flight | Lifetime        | OZ                |
| N/A       | Middeck Locker Equivalent                                | 2        | N/A             | Flight | 3-months        | OZ3               |
| No        | T61p Laptop  | 1        | SEG33115360-303 | Flight | 3-months        | SSP               |
| No        | DC Power Supply Cable (28vdc)                            | 1        | SEG39129264-305 | Flight | 3-months        | SSP               |
| No        | Enhanced T61p 16vdc Power Cable                          | 1        | SEG33116459-301 | Flight | 3-months        | SSP               |
| No        | T61p 28vdc Power Supply (28vdc-to-16vdc Power Converter) | 1        | SEG33116428-301 | Flight | 3-months        | SSP               |
| No        | AMS Turn-Around Plug                                     | 1        | 38P77W423P4     | Flight | 3-months        | SSP               |
| No        | AMS 60GB Hard Drive, A31p                                | 2        | SEG33115359-301 | Flight | 3-months        | SSP               |
| No        | Ultrabay Adapter Assembly, A31p                          | 2        | SEG33115362-301 | Flight | 3-months        | SSP               |

Note 1: The ISS Program provided the listed GFE equipment which are integrated into the AMS-02 external system assembly: 1-Umbilical Mating Assembly (UMA) Passive Half Assembly, 1-Flight Releasable Grapple Fixture (FRGF), 1-Power Video Grapple Fixture (PVGf), 1-External Berthing Camera System (EBCS), and 1-Remotely Operated Electrical Umbilical (ROEU) Passive Disconnect Assembly (PDA).

Note 2: The AMS-02 Project procured the listed GFE equipment from NASA/JSC which are integrated into the AMS-02 external system assembly: 1-Worksite Interface Fixture (WIF), and 9-EVA handrails.

Station Support Equipment (SSE)

| SSE Item Name              | Quantity | Part Number     | Use    | Duration of Use    | Hardware Provider |
|----------------------------|----------|-----------------|--------|--------------------|-------------------|
| Desk Top Plate Assembly    | 1        | SED33108703-304 | Flight | Dedicated Lifetime | EC6               |
| Multi-Use Bracket Assembly | 1        | SEG33107631-301 | Flight | Dedicated Lifetime | EC6               |

Ground Data Services requirements identified by AMS-02 are documented in the following table in order to support mission planning, operations, and coordination. Ground data services [also known as Huntsville Operations Support Center services] shall be negotiated with Marshall Space Flight Center Ground Support Requirements Team. The ISS includes many diverse users with a myriad of data requirements. Data downlink is balanced among users, and may not be available to all payloads at all times. Payloads requiring collection of large amounts of data should include on-orbit data stowage to enable deferred downlink.

Availability and approval of the payload's ground data services requirements are considered complete upon signing of this PIA.

Ground Data Services

| Ground Data Services Requirements   | Operating Location From               | Operating Location To   | Data Rate (Mbits/s)                                | POIC Process Data  | Voice Distribution System | Internet Voice Distribution System |
|---|---------------------------------------|---|--|--|---------------------------|------------------------------------|
| Payload Science (Sci) / Engineering (Eng) Data / POCC Services and HOSC Resources | POIC                                  | JSC AMS-02 POCC B/30S/Room 215A MCC-H   | 13 Mbits/s average - High Rate Data Bus [DOWN] (1) | Yes - Nominal 1 command per second. Note 1 Note 2 Note 3 |                           |                                    |
| Payload Sci/Eng Data / POCC Services & HOSC Resources                             | POIC                                  | European Organization for Nuclear Research (CERN) POCC, B946/R-004, B892/R-B01, Geneva, Switzerland | 13 Mbits/s average - High Rate Data Bus [DOWN] (1) | Yes - Nominal 1 command per second. Note 1 Note 2 Note 3 |                           |                                    |
| Payload Science (Sci) / Engineering (Eng) Data / POCC Services and HOSC Resources | JSC AMS-02 POCC B/30S/Room 215A MCC-H | POIC  | 8 Mbits/s Periodic - High Rate Data Bus [UP] (1)   | Yes Note 1 Note 2  |                           |                                    |

Note 1: Details provided in POIC Ground Data Services Requirements document P/L SW RCS #:45. Summary of general data services required: Real-Time (R/T) access to AMS-02 Health and Status (H&S) data, R/T AMS-02 high telemetry rate science data, R/T ISS Broadcast Ancillary Data, R/T User Defined GSE packets, DUMP2 data, GSE Packet Definition and Distribution Services, Planning Data Set (PPS)/User Requirements Collection (URC) accounts, EHS Personal Computer Services, OSTPV short term planning services, Aristotle Web Server Access account.

Note 2: The AMS-02 Project will provide software and support for file transfer of uplink command services [ISS payload command services limited only to two (2) AMS-02 POCCs: MCC-H/Room 215A and CERN network connectivity services and resources] and telemetry parameters services to all AMS-02 POCCs.

Note 3: Some parameters in the AMS-02 Critical Health Data can be decommutated and displayed at the POIC; however, AMS-02 has no requirement for POIC processing of payload command or telemetry data.

Note 4: IVoDS for voice distribution to remote locations. If voice distribution is through other means when AMS-02 operates, four (4) voice interfaces are required to be provided. Request the creation of a conference voice loop (talk/monitor) for AMS-02 coordination within/between the AMS-02 POCCs, i.e., JSC/MCC-H, CERN, Taiwan, and MIT network connectivity services.

Note 5: There are three (3) pertinent physical addresses involved in the AMS Taiwan POCC setup:

- [Address 1] The address of Academia Sinica where the NASA/HOSC will connect to first is:
  - Academia Sinica Grid Center (ASGC)  
128 Academia Road Sec. 2, Nankang, Taipei 11529, Taiwan
- [Addresses 2 & 3] From ASGC, the AMS-02 Project will connect to a primary POCC at CSIST (Chung-Shan Institute of Science and Technology) and a backup POCC at NCU (National Central University). Their addresses:
  - [Address 2] AMS CSIST POCC  
Building #48, Long Yuan Research Park  
566, Lane 134, Longyuan Road, Longtan Township,  
Taoyuan County, 32544, Taiwan
  - [Address 3] AMS NCU POCC  
National Central University, Building S4  
300 Zhong-Da Road,  
Jhong-Li, TaoYuan, 32054, Taiwan

The AMS-02 Project agrees to provide the Payload Furnished Equipment listed in the SSP Payload Furnished Equipment table and the ISS Payload Furnished Equipment table. Availability and approval of the AMS-02 provided flight hardware is considered complete with approval of this PIA and approval of the statements within the STS-134/ULF-6 MIP with the Space Shuttle Program.

#### AMS-02 SSP Payload Furnished Equipment

| Delivered | Equipment  | Quantity | Part Number     | Use    | Duration of Use | Hardware Provider |
|-----------|--|----------|-----------------|--------|-----------------|-------------------|
| No        | AMS USB A/B Cable                                      | 2        | SED39136130-801 | Flight | Note 1          | AMS               |
| No        | USBR422  | 2        | SED39137921-301 | Flight | Note 1          | AMS               |
| No        | DDRS-02 PDIP Cable                                     | 2        | SED39136111-301 | Flight | Note 1          | AMS               |
| No        | AMS Extension Cable                                    | 2        | SED39137973-301 | Flight | Note 1          | AMS               |
| No        | AMS Playback Cable                                     | 2        | SED39137930-301 | Flight | Note 1          | AMS               |
| No        | AMS Orbiter Communications Adapter (OCA) Adapter Cable | 2        | SED39137971-301 | Flight | Note 1          | AMS               |
| No        | AMS-02 RS-422 T-0 Cable                                | 2        | SED39136112-302 | Flight | Note 1          | AMS               |

Note 1: Duration of use of this listed AMS-02 provided flight hardware on the Orbiter will be from post insertion through the AMS-02 external system installation onto the S3 Integrated Truss Assembly (ITA) payload attach site and payload receipt of power from ISS during docked operations.



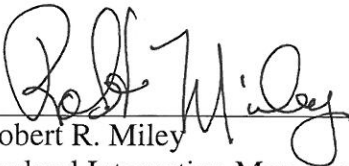
The AMS-02 basic requirements and remarks are listed in the Basic Payload Data and Requirements table Payload and are for planning purposes.

### Basic Payload Data and Requirements

| Payload Requirements        | Orbiter Cargo Bay Resources Required   | ISS External Resources Required  |
|-----------------------------|--|--|
| Payload On-orbit Science    |  | Payload mission is 10-years plus of continuous science collection with a permanent magnet system operation.  |
| Payload On-orbit Mass       |  | External system ~15,300 lbs installed on the zenith/inboard S3 ITA PAS #2 site.<br><br>Internal system DDRS, ~140 lbs in pressurized volume.   |
| Payload Up Mass – Ascent    | Transport ~15,300 lbs in Orbiter cargo bay utilizing direct interfaces via four longeron trunnions and one keel trunnion.<br><br>Transport DDRS, ~70 lbs in middeck stowage.   |  |
| Payload Down Mass – Descent | Zero (0) lbs   |  |
| Power Loads - Note 1        | Up to 2,400 watts @ 120vdc continuous power post-insertion in Orbiter cargo bay.<br><br>Up to 90 watts @ 28vdc continuous power post-insertion for dedicated A31p laptop Orbiter operations.   | Up to 2,400 watts continuous power for nominal science operations. Variable operational power loads: 400 watts @ 120vdc minimum to 2,400 watts @ 120vdc peak.<br><br>Up to 90 watts @ 28vdc continuous power post-insertion for dedicated T61p laptop Orbiter operations.  |
| Data System                 | AMS-02 will generate an average of 4 Mbits/s of RS422 for downlink on Ku-Band.<br><br>AMS-02 laptop used for playback at up to 4 Mbits/s of RS422 downlink on Ku-Band.<br><br>AMS-02 Payload Data Interleaver (PDI) will be downlink interface for Orbiter S-band. | AMS-02 will generate an average of 13 Mbits/s of HRDL for downlink on Ku-Band.<br><br>AMS-02 laptop will generate 10 kbps of housekeeping data on the MRDL.<br><br>AMS-02 critical health and housekeeping data will be generated for downlink via ISS S-Band system during ISS Ku-Band disruptions. The availability of ISS S-Band system downlink is to be managed by the ISS real-time flight control team pending ISS operational priorities and |

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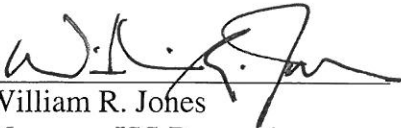
  
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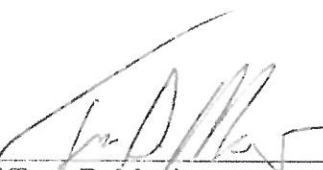
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